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Research Article

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Increasing rice production in sodic soil through ferti-irrigation with distillery spentwash

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Summary

Field experiment was conducted in sodic soil (pH 8. 9 ESP- 31.5 %) to study the extent of reclamation achieved due to basal application of raw spentwash (RSW) and to study the effect of primary spentwash (SW) used for ferti-irrigation on extent of reclamation incidentally achieved due to spentwash application in comparison with gypsum and also on growth and yield of paddy. Highest grain, straw yield and nutrient uptake was recorded in RSW @ 100 % GR+100 % RDN through SW (3 splits) and lowest was recorded in T_1 which received gypsum @50 % GR + recommended NPK. Per cent increase in grain yield 47.34 per cent (T_9) was noticed in spentwash amended plot compared to gypsum treatment (T_1). Reduction in soil pH was highest in T_9 (RSW @ 100% GR+100% RDN through SW (3splits)) and lowest in T_1 (Gypsum@50% GR+ Rec.NPK). Application of RSW @ 100% GR+100% RDN through SW (4 splits) recorded significantly lower exchangeable sodium content and ESP compared to other treatments. The cost economics of cultivation revealed that highest benefit cost ratio (2.69) was obtained with raw spentwash @ 100 % GR+ 100 % RDN through treated spentwash in 3 splits while the lowest 0.53 was with gypsum @ 100 % GR+ rec.NPK.

Key words : Distillery spentwash, Ferti-irrigation, Rice production, Soil properties, Cost economics

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Introduction

Distillery spentwash a wastewater discharged by distilleries can be utilized as a nutrient rich resource for crop production. The raw spentwash is highly acidic in nature and possess high salt content and higher amounts of dissolved and suspended solids Though the spentwash has a high BOD and COD load, also has appreciable quantities of calcium along with plant nutrients and easily oxidisable organic matter. The enormous quantities of plant nutrients present in spentwash offers an excellent opportunity to use it as a liquid fertilizer, thus enabling the farmers to save on fertilizers and at the same time achieve higher yields of crops.

Resource and Research Methods

Field experiment was conducted in sodic soil at VC Farm, Mandya, during summer 2009 to study the extent of reclamation achieved due to basal application of raw spentwash and to study the effect of primary spentwash used for ferti-irrigation on extent of reclamation incidentally achieved due to spentwash application in comparison with gypsum and also on growth and yield

of paddy.

The soil was sandy clay loam in texture, alkaline in reaction with pH 8.9, has electrical conductivity of 0.64 dS m^{-1} and exchangeable sodium percentage of 31.5 per cent. The field experiment was laid out in Randomized Complete Block Design with fourteen treatments and three replications with Paddy (IR-30864) as test crop.

Treatments :

T_1 Gypsum @50% GR + Recommended NPK

T_2 Gypsum @100% GR + Recommended NPK

T_3 RSW @ 50% GR +50% RDN through TSW (3splits)

T_4 RSW @ 50% GR +50% RDN through TSW (4 splits)

T_5 RSW @ 50% GR +100% RDN through TSW (3splits)

T_6 RSW @ 50% GR +100% RDN through TSW (4 splits)

T_7 RSW @ 100% GR+50% RDN through TSW (3 splits)

T_8 RSW @ 100% GR+50% RDN through TSW (4 splits)

T_9 RSW @ 100% GR+100% RDN through TSW (3splits)

T_{10} RSW @ 100% GR+100% RDN through TSW (4splits)

T_{11} 100% RDN (50% basal RSW + 50% TSW in 3 splits)

T_{12} 100% RDN (50% basal RSW + 50% TSW in 4splits)

T_{13} 150% RDN (50% basal RSW + 50% TSW in 3 splits)

T_{14} 150% RDN (50% basal RSW + 50% TSW in 4 splits).

where, RDN- Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK- Recommended dose of potassium, RSW- Raw spentwash, TSW- Treated spentwash (primary treated).

Imposition of treatments :

The land was ploughed with tractor drawn mould board plough followed by harrowing and leveling. Layout was made according to the experimental design and plot size for planting paddy. After digging drainage channels and making bunds, calculated quantity of gypsum and raw spentwash were applied to the plots as per lay out plan one month before planting. Plots were leached with the good quality water and proper drainage was provided to leach out excess salts. The crop was harvested plot wise close to the ground level during third week of June 2009, detrashed, bundled and stocked plot wise before recording the yield.

Observations :

The bio metric observations like plant height, number of tillers, number of panicles, panicle length, number of seeds per panicle, were recorded. The grain and straw yield of each treatment was recorded and expressed in quintals per hectare. The representative soil samples were collected from each plot at different crop growth stages *viz.*, at tillering, flowering stage and after harvest stage of crop from 0-15 cm depth.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Growth parameters :

The data pertaining to effect of ferti-irrigation of spentwash on plant height number of productive tillers, number of seeds per panicle, thousand grain weight of paddy after reclamation of sodic soil are presented in Table 1.

Highest plant height of 65.01cm was recorded with T_{10} treatment receiving RSW @ 100% GR+100% RDN through SW (4 splits) followed by T_9 (RSW @ 100% GR+100% RDN through SW (3 splits), T_8 (RSW @ 100% GR+50% RDN through SW (4 splits) and T_7(RSW @ 100% GR+50% RDN through SW (3 splits) recorded 64.61cm, 63.11cm, 62.03 cm, respectively.

Highest (14.5) number of productive tillers was recorded in T_{10} RSW @ 100% GR+100% RDN through SW (4 splits), $T_{9.}$ $T_{8.}$ $T_{7,}$ T_6 compared to T_1 (Gypsum @50% GR+recommended NPK) and T_2 (Gypsum @100% GR + recommended NPK) which recorded 10.5 and 11.2 number of tillers. Highest (137) number of seeds per panicle was recorded with application RSW @ 100% GR+100% RDN through SW 3splits) followed by T_7, T_{10}, T_8, T_5 which recorded 136,135,134 and 130 number of seeds per panicle.

Highest thousand grain weight of 34.38g was recorded with T_9 (RSW @ 100% GR+100% RDN through SW (3 splits), followed by T_8 (32.67g), T_{10} (32.32 g) which were at par with each other. Lowest thousand grain weight (22.64 g) was recorded in (Gypsum @50% GR + recommended NPK). The increase in growth and yield parameters might be due to proper utilization of major and micronutrients by the crop. Similar results were obtained by Pujar and Manjunathaiah (1996); Doddagoudar and Alagawadi (2001) and Ananthkumar (2002).

Grain and straw yield :

The data on the grain yield of paddy as influenced by ferti-irrigation of spentwash after reclamation of sodic soil are presented in Table 1. Significantly highest grain

Table 1: Effect of ferti-irrigation of spentwash on growth and yield (q ha^{-1}) of paddy

Parameters	Plant height cm	No.of tillers	No.of seeds / panicle	Thousand grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1 Gypsum @50% GR + Recommended NPK	33.34	10.5	115	22.64	25.62	31.25
T_2 Gypsum @100% GR + Recommended NPK	35.29	11.2	120	24.72	33.02	38.21
T_3 RSW @ 50% GR +50% N through SW (3 splits)	54.25	12.5	123	25.61	32.0	47.42
T_4 RSW @ 50% GR +50% N through SW (4 splits)	53.25	12.0	126	27.82	34.0	48.29
T_5 RSW @ 50% GR +100% N through SW (3 splits)	56.33	12.5	130	27.71	35.75	49.40
T_6 RSW @ 50% GR +100% N through SW (4 splits)	56.03	13.5	129	28.12	35.0	48.54
T_7 RSW @ 100% GR+50% N through SW (3 splits)	62.03	13.5	136	30.40	36.0	51.50
T_8 RSW @ 100% GR+50% N through SW (4 splits)	63.11	14.0	134	32.67	37.25	50.86
T_9 RSW @ 100% GR+100% N through SW (3 splits)	64.61	14.0	137	34.38	37.75	53.45
T_{10} RSW @ 100% GR+100% N through SW (4 splits)	65.01	14.5	135	32.32	36.75	54.50
T_{11} 100% N (50 % N through RSW +50% N through SW in 3 splits)	48.37	11.5	120	25.69	32.98	44.97
T_{12} 100% N (50 % N through RSW +50% N through SW in 4 splits)	47.49	12.0	122	26.12	32.65	45.25
T_{13} 150% N (50 % N through RSW +50% N through SW in 3 splits)	51.33	12.5	123	26.88	33.14	45.65
T_{14} 150% N(50% N through RSW +50% N through SW in 4 splits)	52.01	12.0	122	27.01	33.52	45.15
S.E.±	0.71	0.43	4.68	0.89	0.36	0.37
C.D. (P=0.05)	2.06	NS	13.62	2.59	1.06	1.09

NS=Non-significant

Table 2 : Effect of ferti-irrigation of primary spentwash on pH, EC and OC content of soil after harvest of paddy

Parameters	pH (1:2)	EC (dS m^{-1})	OC (%)
T_1 Gypsum @50% GR + Recommended NPK	8.79	0.69	0.48
T_2 Gypsum @100% GR + Recommended NPK	8.60	0.75	0.50
T_3 RSW @ 50% GR +50% N through SW (3 splits)	8.39	0.82	0.68
T_4 RSW @ 50% GR +50% N through SW (4 splits)	8.32	0.87	0.69
T_5 RSW @ 50% GR +100% N through SW (3 splits)	8.34	0.97	0.70
T_6 RSW @ 50% GR +100% N through SW (4 splits)	8.31	1.02	0.72
T_7 RSW @ 100% GR+50% N through SW (3 splits)	8.29	0.98	0.75
T_8 RSW @ 100% GR+50% N through SW (4 splits)	8.25	1.09	0.77
T_9 RSW @ 100% GR+100% N through SW (3 splits)	8.19	1.14	0.78
T_{10} RSW @ 100% GR+100% N through SW (4 splits)	8.11	1.40	0.81
T_{11} 100% N (50 % N through RSW +50% N through SW in 3 splits)	8.56	0.78	0.58
T_{12} 100% N (50 % N through RSW +50% N through SW in 4 splits)	8.53	0.82	0.60
T_{13} 150% N (50 % N through RSW +50% N through SW in 3 splits)	8.50	0.93	0.65
T_{14} 150% N (50% N through RSW +50% N through SW in 4 splits)	8.51	0.95	0.67
S.E.±	0.22	0.02	0.01
C.D.(P=0.05)	0.68	0.06	0.03

yield of 37.75 q ha^{-1} was recorded in T_9 (RSW @ 100% GR+100% RDN through SW (3 splits), T_8 (37.25 q ha^{-1}) and T_{10} (36.75 q ha^{-1}. Lowest grain yield was recorded in T_1 (25.62 q ha^{-1}) which received gypsum @ 50% GR + recommended NPK.

Significantly highest straw yield of 54.50 q ha^{-1} was recorded in T_{10} (RSW @ 100% GR+100% RDN through SW (4 splits) followed by T_9 (53.45 q ha^{-1}). RSW @ 50% GR +100% RDN through SW (3 splits) (T_5) recorded 49.40 q ha^{-1} followed by T_6 (48.54 q ha^{-1}), T_4 (48.29 q ha^{-1}) and was found significantly superior over T_2 (38.21 q ha^{-1}) and T_{11} (44.97 q ha^{-1}).

The higher grain and straw yield in these treatments is attributed to improvement in various growth and yield parameters *viz.*, plant height, number of tillers, number of seeds per panicle and thousand grain weight due to application of distillery spentwash. Also application of raw spentwash one month before transplanting might have improved the physical conditions of the soil by replacing exchangeable sodium with calcium and also over all nutrients status of soil. Also application of treated spentwash through irrigation has provided the nutrient requirement of crop at later stages. Improved physical and chemical properties of soil helped in better uptake of water and nutrients thus resulting in higher yield.

Chemical properties of soil :

The data pertaining to effect of ferti-irrigation of spentwash pH, electrical conductivity and organic carbon content after reclamation of sodic soil are presented in Table 2.

Soil pH :

Soil pH differed significantly due to ferti-irrigation of spentwash (Table 2). Reduction in soil pH was highest in T_9 (RSW @ 100% GR+100% RDN through SW (3 splits) and lowest (8.79) was in T_1 (Gypsum @ 50% GR+ Rec.NPK). This might be due to good amount of calcium present in raw spentwash compared to gypsum which was not sufficient for replacing sodium on the exchange complex.

Electrical conductivity :

In general, there was significant increase in soil EC in plots receiving spentwash compared to gypsum applied plots. Significantly highest EC (1.40 dS m^{-1}) value was recorded in T_{10} which received RSW @ 100% GR+100% RDN through TSW (4 splits) followed by T_9 (RSW @ 100% GR+100% RDN through TSW (3 splits)), T_8 (RSW @ 100% GR+50% RDN through TSW (4 splits)) which recorded values (1.14 dS m^{-1}) and (1.09 dS m^{-1}) compared to values (0.69 dS m^{-1}) and (0.75 dS m^{-1}) recorded by T_1 gypsum @ 50% GR+ Rec.NPK and T_2 (gypsum @ 100% GR), respectively. Increase in soil EC after effluent application was also reported by Jadhav and Savant (1975); Pathak *et al.*(1999); Scandalaris *et al.* (1987); Zalawadia and Raman (1994) and Joshi *et al.* (1996). The results are in accordance with the findings of Baskar *et al.* (2003) who reported increased EC in soil due to application of distillery spentwash.

Organic carbon :

Significant accumulation of OC (0.81%) in soil was noticed in T_{10} RSW @ 100 % GR+100 % RDN through SW (4 splits) followed by T_9 RSW @ 100 % GR+100 % RDN through TSW (3 splits) (0.78%), T_8 RSW @ 100 % GR+50 % RDN through TSW (4 splits) (0.77%) which was significantly superior over T_1 gypsum @50 % GR + recommended NPK (0.48 %) and T_2 gypsum @100% GR + recommended NPK (0.50 %) which received gypsum @ 50 % GR and 100 % GR, respectively. The increase in organic carbon content of soil can be attributed to the fact that effluent contained high organic load which triggered the microbial activity and contributed for increase in organic carbon content. The results are line with Gurumurthy (1996): Mattiazzo and Gloria (1985) and Singh and Bahadur (1998). Pathak *et al.* (1999) also reported that significantly high organic carbon was accumulated in the soil irrigated with effluent.

Avail. NPK content of soil :

The data pertaining to the effect of ferti-irrigation of primary spentwash on available NPK (kg ha^{-1}) content of soil at different growth stages of paddy are presented in Table 3.

Available nitrogen :

At tillering stage, ferti-irrigation of spentwash significantly influenced the available nitrogen content of soil. Significantly highest available N content was recorded in T_9 RSW @ 100% GR+100% RDN through TSW (4 splits) (439.9 kg ha^{-1}) followed by T_8 RSW @ 100 % GR+100 % RDN through TSW (4 splits) (436.5 kg ha^{-1}) and T_3 (438.3 kg ha^{-1}).

Significantly lowest available nitrogen content was recorded in T_1 gypsum @50 % GR + recommended NPK

Table 3 : Effect of ferti-irrigation of primary spentwash on available NPK (kg ha^{-1}) content of soil at different growth stages of paddy

Parameters	Maximum tillering stage			Flowering stage			After harvest		
	N	P	K	N	P	K	N	P	K
T_1 Gypsum @50% GR + Recommended NPK	226.4	18.7	303.7	200.6	16.2	286.1	186.9	14.2	279.2
T_2 Gypsum @100% GR + Recommended NPK	232.5	19.4	313.4	198.4	17.4	292.4	182.4	14.6	286.8
T_3 RSW @ 50% GR +50% N through SW (3 splits)	438.3	22.3	387.1	386.8	20.8	369.6	374.8	19.4	342.6
T_4 RSW @ 50% GR +50% N through SW (4 splits)	428.4	22.5	384.4	387.4	20.4	367.4	363.4	19.3	356.7
T_5 RSW @ 50% GR +100% N through SW (3 splits)	432.7	23.2	388.5	399.2	21.6	352.8	378.8	20.8	340.5
T_6 RSW @ 50% GR +100% N through SW (4 splits)	424.6	23.5	386.2	392.1	21.9	359.6	368.3	20.6	342.3
T_7 RSW @ 100% GR+50% N through SW (3 splits)	426.3	26.4	403.6	397.2	23.3	375.3	363.2	23.0	350.8
T_8 RSW @ 100% GR+50% N through SW (4 splits)	436.5	27.0	413.3	391.4	22.8	382.3	378.6	21.6	345.7
T_9 RSW @ 100% GR+100% N through SW (3 splits)	439.9	28.6	422.2	416.8	25.6	388.5	374.7	24.1	368.7
T_{10} RSW @ 100% GR+100% N through SW (4 splits)	433.4	28.7	426.1	384.3	26.2	394.6	371.8	24.6	371.1
T_{11} 100% N (50 % N through RSW +50% N through SW in 3 splits)	306.8	19.8	363.2	282.6	17.8	332.4	272.1	16.4	312.6
T_{12} 100% N (50 % N through RSW +50% N through SW in 4 splits)	310.7	20.3	369.3	286.2	17.4	335.5	269.5	16.2	308.3
T_{13} 150% N (50 % N through RSW +50% N through SW in 3 splits)	334.8	20.7	377.4	299.1	18.6	348.7	287.3	17.8	320.4
T_{14} 150% N (50% N through RSW +50% N through SW in 4 splits)	356.7	18.7	378.4	301.5	18.2	350.6	285.4	18.0	321.8
S.E.±	3.09	0.87	2.20	5.76	0.02	2.35	8.62	2.37	7.77
C.D. (P=0.05)	8.97	2.53	6.41	16.73	0.05	6.83	25.07	NS	22.58

NS= Non-significant

Table 4 : Effect of ferti-irrigation of primary spentwash on exchangeable Ca, Mg, Na content of soil after harvest of paddy

Parameters	Ca cmol (p+) kg^{-1}	Mg cmol (p+) kg^{-1}	Na cmol (p+) kg^{-1}	ESP (%)
T_1 Gypsum @50% GR + Recommended NPK	6.30	2.50	6.80	31.68
T_2 Gypsum @100% GR + Recommended NPK	7.10	2.80	5.90	29.43
T_3 RSW @ 50% GR +50% N through SW (3 splits)	7.30	3.53	5.70	27.89
T_4 RSW @ 50% GR +50% N through SW (4 splits)	7.50	3.47	5.60	27.61
T_5 RSW @ 50% GR +100% N through SW (3 splits)	7.60	3.60	5.80	28.52
T_6 RSW @ 50% GR +100% N through SW (4 splits)	7.57	3.60	5.70	29.01
T_7 RSW @ 100% GR+50% N through SW (3 splits)	8.30	3.80	5.40	25.46
T_8 RSW @ 100% GR+50% N through SW (4 splits)	8.40	3.90	5.30	24.67
T_9 RSW @ 100% GR+100% N through SW 3 splits)	8.60	4.03	5.40	26.28
T_{10} RSW @ 100% GR+100% N through SW (4 splits)	8.80	4.17	5.20	26.12
T_{11} 100% N (50 % N through RSW +50% N through SW in 3 splits)	6.50	3.20	6.60	31.81
T_{12} 100% N (50 % N through RSW +50% N through SW in 4 splits)	6.70	3.30	6.50	31.62
T_{13} 150% N (50 % N through RSW +50% N through SW in 3 splits)	6.90	3.50	6.20	30.54
T_{14} 150% N(50% N through RSW +50% N through SW in 4 splits)	7.10	3.60	6.20	30.38
S.E.±	0.45	0.25	0.03	1.2
C.D.(P=0.05)	1.31	0.71	0.08	3.9

(226.4 kg ha^{-1}) which was at par with T_2 gypsum @100 % GR + recommended NPK (232.5 kg ha^{-1}) which received gypsum @ 50 % GR and 100 % GR.

At flowering and harvest stages, available nitrogen content of soil followed the similar trend as that at tillering stage. RSW @100 % GR recorded highest available nitrogen content (378.8 kg ha^{-1}) followed by RSW @ 50 % GR, 150 % and 100 % RDN through spentwash and were significantly superior over gypsum @ 50 and 100 % GR (186.9 and 182.4 kg ha^{-1}), respectively.

Available phosphorus :

At tillering stage, ferti-irrigation of spentwash significantly influenced the available phosphorus content of soil. Significantly highest available P content was recorded in T_{10} RSW @ 100 % GR+100 % RDN through TSW (4 splits) (28.7 kg ha^{-1}) followed by T_9 RSW @ 100 % GR+100 % RDN through TSW (3 splits) (28.6 kg ha^{-1}), T_8 RSW @ 100 % GR+50 % RDN through TSW (4 splits) (27.0 kg ha^{-1}) and was significantly superior over 100 and 150 % RDN through spentwash, gypsum @50 % GR (18.7 kg ha^{-1}) and 100 % GR (19.4 kg ha^{-1}).

At flowering stage, available phosphorus content of soil followed the similar trend as that at tillering stage. Highest available P content was recorded in T_{10} (26.2 kg ha^{-1}) followed by T_9 (25.6 kg ha^{-1}) and was significantly superior over 100 and 150 % RDN through spentwash, gypsum @50 % GR (16.2 kg ha^{-1}) and 100 % GR (17.4 kg ha^{-1}).

At harvest, there was no significant change in available P content of soil. However, highest P content was recorded in T_{10} (24.6 kg ha^{-1}) and lowest (14.2 kg ha^{-1}) in T_1 (gypsum @50% GR+ rec.NPK).

Available potassium :

At tillering stage, ferti-irrigation of spentwash significantly influenced the available potassium content of soil. Significantly highest available K content was recorded in T_{10} (426.1 kg ha^{-1}) followed by T_9 (422.2 kg ha^{-1}), T_8 (413.3 kg ha^{-1}) and was significantly superior over RSW @ 50 % GR and 100 and 150 % RDN through spentwash. Significantly lowest available K content was recorded in T_1 (303.7 kg ha^{-1}) which was at par with T_2 (313.4 kg ha^{-1}) which received gypsum @50 % GR and 100 % GR.

At flowering and harvest stage, available K content of soil followed the similar trend as that at tillering stage. At harvest, RSW @100 per cent GR recorded highest available potassium content (371.1kg ha^{-1}) followed by RSW @50 per cent GR, 150 per cent and 100 per cent RDN through spentwash and was significantly superior over gypsum@50 and 100 % GR (286.8 and 279.2 kg ha^{-1}), respectively.

This trend of results in spentwash applied plots might be due to higher amount of nutrients especially nitrogen

Table 5: Effect of ferti- irrigation of spentwash on gross returns, net returns and B:C ratio of paddy

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B :C ratio
T_1 Gypsum @50% GR + Recommended NPK	33.34	10.5	34481	22371	-12110	0.65
T_2 Gypsum @100% GR + Recommended NPK	35.29	11.2	53981	28709	-25272	0.53
T_3 RSW @ 50% GR +50% RDN through SW (3 splits)	54.25	12.5	12410	28445	16035	2.29
T_4 RSW @ 50% GR +50% RDN through SW (4 splits)	53.25	12.0	12410	30097	17687	2.43
T_5 RSW @ 50% GR +100% RDN through SW (3 splits)	56.33	12.5	12410	31564	19154	2.54
T_6 RSW @ 50% GR +100% RDN through SW (4 splits)	56.03	13.5	12410	30912	18502	2.49
T_7 RSW @ 100% GR+50% RDN through SW (3 splits)	62.03	13.5	12410	31890	19480	2.57
T_8 RSW @ 100% GR+50% RDN through SW (4 splits)	63.11	14.0	12410	32852	20442	2.65
T_9 RSW @ 100% GR+100% RDN through SW (3 splits)	64.61	14.0	12410	33407	20997	2.69
T_{10} RSW @ 100% GR+100% RDN through SW (4 splits)	65.01	14.5	12410	32670	20260	2.63
T_{11} 100% RDN (50 % RDN through RSW +50% RDN through SW in 3 splits)	48.37	11.5	13498	29082	15584	2.15
T_{12} 100% RDN (50 % RDN through RSW +50% RDN through SW in 4 splits)	47.49	12.0	13498	28835	15337	2.14
T_{13} 150% RDN (50 % RDN through RSW +50% RDN through SW in 3 splits)	51.33	12.5	13464	29251	15787	2.17
T_{14} 150% RDN(50% RDN through RSW +50% RDN through SW in 4 splits)	52.01	12.0	13464	29525	16061	2.19

Note: Urea @ Rs. 4.80/ kg, SSP@ Rs. 3.705/ kg, MOP @ Rs. 4.50/ kg, Gypsum@ Rs.3/kg ,Paddy -@ Rs.800/q, Paddy straw-@ Rs.60/q,

and potassium added through very high levels of spentwash.

Exchangeable Ca, Mg, Na and ESP content of soil :

The data pertaining to the effect of ferti-irrigation of primary spentwash on exchangeable Ca, Mg, Na and ESP of soil after harvest of paddy (Table 4).

Exchangeable calcium :

Application of raw spentwash had significant influence on exchangeable Ca content of soil (Table 4). RSW @100 per cent GR recorded highest exchangeable Ca content (8.80 c mol (p+) kg^{-1}) followed by RSW @50 per cent GR(7.60 c mol (p+) kg^{-1}) but was significantly superior over 150 per cent (7.10 c mol (p+) kg^{-1}), 100 per cent RDN through spentwash (6.7 c mol (p+) kg^{-1}), gypsum@ 50 and 100 per cent GR (6.3 and 7.1 c mol (p+) kg^{-1}), respectively.

Similarly, RSW @100 per cent GR recorded highest exchangeable Mg content (4.17 c mol (p+) kg^{-1}) followed by RSW @50 per cent GR (3.60 c mol (p+) kg^{-1}) and 100 per cent RDN through spentwash (3.30 c mol (p+) kg^{-1}), gypsum@ 50and 100 per cent GR(2.50 and 2.80 c mol (p+) kg^{-1}), respectively.

This is attributed to the presence of appreciable quantities of Ca and Mg in spentwash which upon application to soil increased the Ca and Mg content (Patil *et al.,* 1987; Taluk and Medeiros, 1989; Pawar *et al.*, 1992; Bhat, 1994; Zalwadia *et al.,* 1997; Paula *et al.*, 1999; Sukanya and Meli, 2004 and Madusudhana, 2006).

Exchangeable sodium and exchangeable sodium percentage :

Exchangeable sodium content of soil was significantly influenced by ferti-irrigation of spentwash is presented in (Table 4). Significantly lowest exchangeable Na content was recorded with application of raw spentwash @ 100 per cent GR (5.20 c mol (p+) kg^{-1}) and raw spentwash @ 50 per cent GR (5.40 c mol (p+) kg^{-1}). Significantly highest value (6.80 c mol (p^+) kg^{-1}) was recorded in T_1 (gypsum 50% GR+Rec.NPK) followed by 100 % RDN through raw spentwash (6.60 c mol (p^+) kg^{-1}) and 150 % RDN (6.20 c mol (p^+) kg^{-1}).

Exchangeable sodium percentage of soil was also significantly influenced by ferti-irrigation of spentwash is presented in (Table 4). Significantly lowest exchangeable sodium percentage was recorded with application of raw spentwash @ 100 % GR (24.67%) and raw spentwash @ 50 % GR (27.61%). Significantly highest value (31.68%) was recorded in T_1 (gypsum 50% GR+ Rec.NPK) followed by 100 % RDN through raw spentwash (31.81%) and 150 % RDN (30.54 %).This may be due to the fairly good amount of calcium present in spentwash which might have replaced the sodium on the exchange complex and also due to leaching because it was held very loosely on the exchange complex compared to calcium and magnesium ions.

Cost economics of ferti- irrigation of primary spentwash :

The lowest total cost of cultivation (12410 $Rs.ha^{-1}$) was recorded in raw spentwash @ 100 % GR+100 % RDN through SW 3 splits (T_9) and highest (53981 Rs. ha^{-1}) was recorded with gypsum @100 % GR + recommended NPK (T_2). Highest gross return (33407 Rs. ha^{-1}) was recorded in raw spentwash @ 100 % GR+100 % RDN through SW 3 splits) (T_9) followed (32852 Rs. ha^{-1}) by raw spentwash @ 100 % GR+50 % RDN through SW (4 splits) (T_8) and least gross return (22371 Rs. ha^{-1}) was recorded with gypsum @50 % GR + recommended NPK (T_1).

Conclusion :

The enormous quantities of plant nutrients present in spentwash offers an excellent opportunity to use it as a liquid fertilizer along with irrigation water, thus, enabling the farmers to save on fertilizers and at the same time achieve higher yields of crops.

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